Optimal Distributed Energy Resource Investment Under a Carbon Emissions Cap

How can distributed energy resources be used to reduce carbon emissions?
How much higher will the energy bill be if carbon emissions reduction targets are met?
How would cost minimizing investment change as carbon emissions constraints become tighter?

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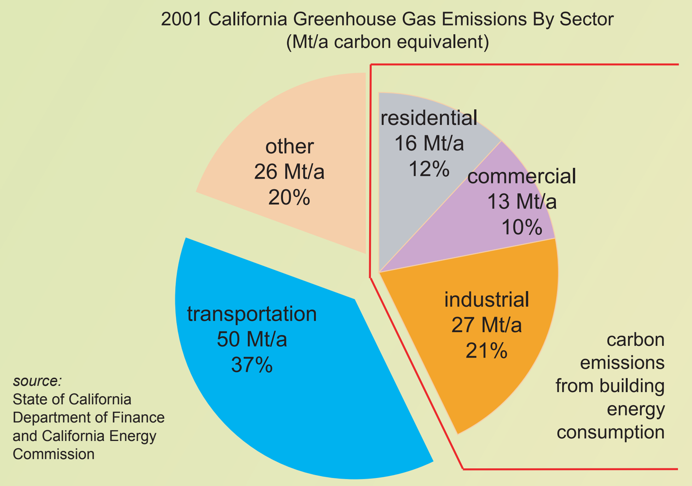
Introduction

Green House Gas Emissions From Building Energy Consumption

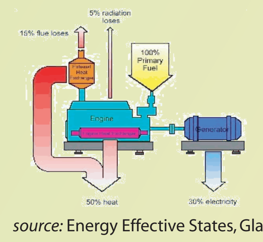
Building energy consumption accounts for 43% of greenhouse gas (GHG) emissions in California. Significant reductions in GHG emissions could be achieved through energy efficiency measures and the use of renewable resources on-site.



Using Distributed Energy Resources to Reduce Primary Energy Consumption

Distributed Energy Resources (DER) are a range of energy conversion and storage technologies including small-scale power generation, thermal and electrical storage, and thermally activated cooling. Technologies include:

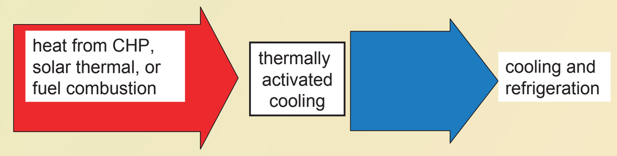
Distributed electricity generation:
reciprocating engines, microturbines, fuel cells, and photovoltaics located at the site of consumption



Combined heat and power (CHP):
distributed electricity generation with waste heat recovery for site heating needs. 60-90% of primary fuel energy can be utilized.

source: Energy Effective States, Glascow, UK

Thermally activated cooling:
Absorption and adsorption chillers use heat, rather than electricity, to provide cooling.



Solar thermal technologies:
Solar thermal collectors can be used to convert solar energy into heat for domestic hot water or to preheat hot water supplied to an absorption chiller. High temperature collectors can provide steam for industrial processes and higher efficiency absorption chillers.

Storage *(not considered in this analysis)*:
Storage devices such as batteries and thermal tanks can be used to improve reliability and to supply energy produced or purchased during a low value time to loads at a higher value time.

source: Bob Jane T-Marts

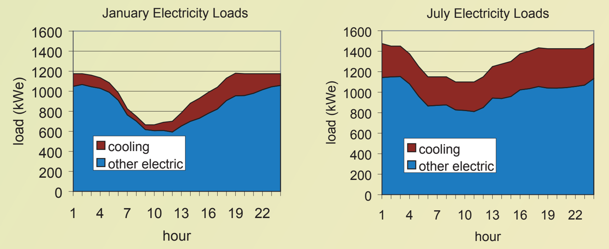
Methods

Identifying and Modeling Candidate Distributed Energy Resource Investments in California

The United States Postal Service Processing and Distribution Center in Redlands, CA was selected as a candidate site.

Large year-round cooling loads at the site are the result of the harsh desert climate plus the mail sorting equipment waste heat.

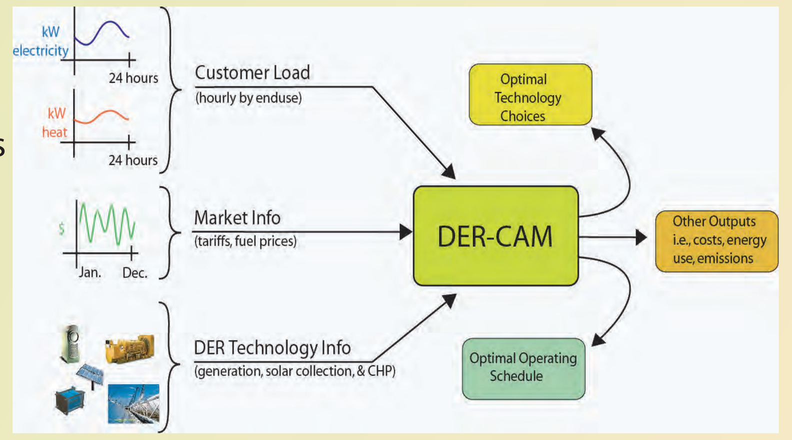
The site has night-time peak loads becuase mail sorting equipment is used mostly at night.



An Optimization Model of DER Investment Under Carbon Caps

The Distributed Energy Resources Customer Adoption Model (DER-CAM) is a site-specific, fully technology neutral DER investment and operation optimization tool developed by the DER team at the Berkeley Lab.

Inputs include
- site hourly electricity and heating load profiles
- energy prices
- DER investment options
- operational constraints such as limits on carbon emissions.



Outputs include
- optimal DER investment
- optimal operating schedule
- performance measures such as annual energy cost, electricity and natural gas consumption, and carbon emissions attributed to energy consumption

Model Parameters

Investment Options (discrete)

	installed cost ($/kW)	electrical efficiency
1000 kW gas turbine	1403	0.22
100 kW microturbine	1700	0.26
250 kW microturbine	1400	0.28
200 kW reciprocating engine	900	0.31
500 kW reciprocating engine	795	0.33

source: Goldstein et al (2003)

Investment Options (continuous)

	fixed cost ($)	variable cost ($/kW)	variable cost ($/ton)	COP
photovoltaics		4240		
absorption chillers				
single effect	20,000	115	405	0.7
double effect	27,000	155	576	1.2
solar collectors				
low temperature		150		
high temperature		1400		

source: EIA (2004), Firestone (2004), Goldstein et al (2003)

Electricity rates

		on-peak	mid-peak	off-peak
energy charge ($/kWh)				
	winter	0.091	n/a	0.043
	summer	0.123	0.071	0.043
demand charge ($/kW monthly peak)				
	winter	8.3	n/a	n/a
	summer	30.5	3.3	n/a

source: SCE (2005)

Natural gas rates

$0.021 to $0.028/kWh
$0.62 to $0.82/therm

source: SoCalGas (2005)

Marginal rate of carbon emissions from California central utility grid

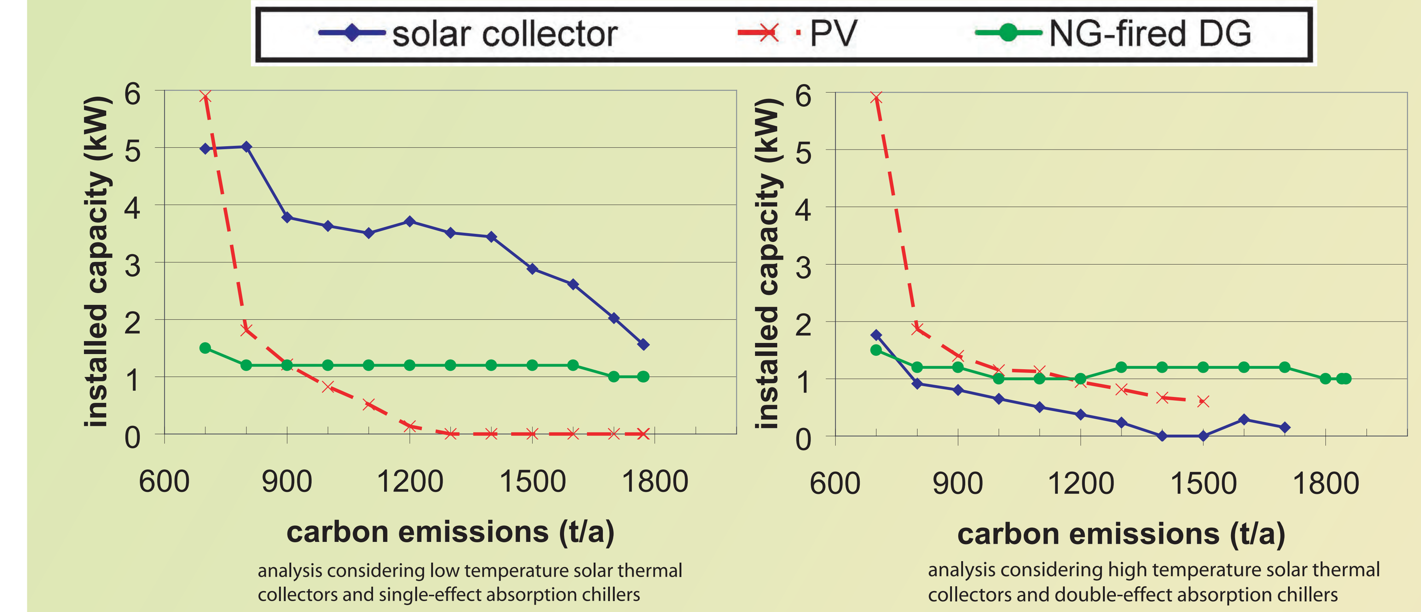
0.22 kgC/kWh

source: Price et al (2002)

Results

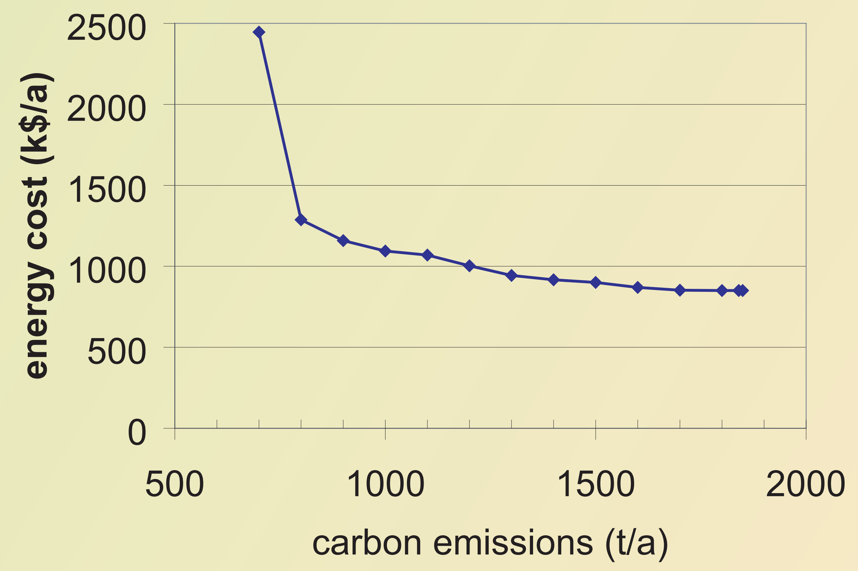
What Technologies are Chosen?

Optimal DER investment varies with the level of carbon cap. For less stringent caps, CHP and low temperature solar thermal collectors provide the cost minimizing solution. For more stringent targets, more solar thermal, and finally photovoltaics, are required.



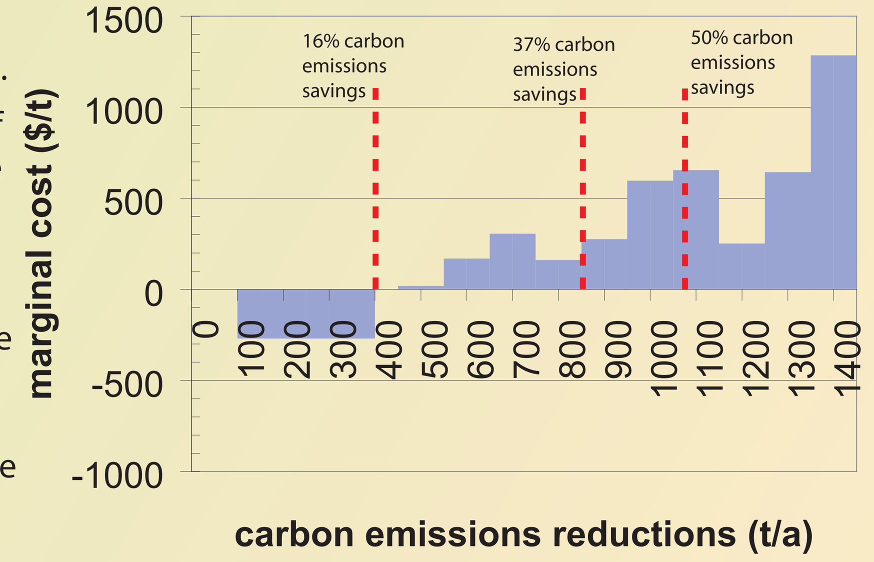
What are the Annual Energy Costs?

This graph shows the minimum site energy costs (including amortized capital costs of DER equipment) as a function of carbon cap. Carbon emissions from energy consumption at the site (including electric utility emissions) are 2150 tons per year without DER and annual energy costs are $932,000.



This graph shows the incremental cost of carbon emissions reductions below the business-as-usual (no DER) level.

- Carbon emissions reductions of 350 t/a (16%) are cost-effective without carbon cap or DER subsidy.
- Reductions of 800 t/a (37%) are possible at the same cost as the business-as-usual (no DER) level.
- Reductions of 50% (1075 t/a) are possible at an average subsidy level of $140/t.



Conclusions

- Distributed energy resources can be used to reduce the carbon emisssions from energy consumption in buildings

- Although not carbon-free, combined heat and power can provide cost-effective carbon mitigation over a wide range of carbon caps by utilzing a higher portion of primary energy than the centralized power grid.

At this site:

-Solar thermal assisted cooling is cost-effective, reducing both electricity consumption and peak loads.

-Low-cost solar collectors for absorption chillers are cost effective without subsidy or carbon cap, but relatively low payoff compared to hassle would discourage adoption.

-With tight carbon caps, more expensive solar collectors for high-efficiency absorption chillers are cost-effective.

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-Reductions of 50% (1075 t/a) are possible at an average subsidy level of $140/t.

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Acknowledgments

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